NASA TECH BRIEF

Technique for Predicting Temperature Distribution in Gases

The problem:

To calculate, by simple equations, the temperature distribution throughout a volume of gas containing distributed radiating heat sources. Ordinarily, heat transfer problems involving gases are very difficult to solve, since the gas heat absorption coefficients are dependent on both the radiation wavelength and the gas temperature. Generally, either approximations or numerical computer solutions or both are required to obtain quantitative answers to specific problems.

The solution:

Equations have been derived for the temperature distribution throughout a heat generating, radiation gas. The equations are simple algebraic equations that require only a slide rule for use. They apply over the entire range of opacities, from zero to infinity, for any heat flux, for a temperature dependent absorption coefficient, and for a non-uniform distribution of volumetric heat sources. Equations are included for spherical, cylindrical, and slab geometries. The equations go to the correct form in the limiting case of a "clear" gas (zero opacity), and they go to the diffusion theory limit for a "black" gas (infinite opacity).

How it's done:

An equation is derived for the temperature distribution normalized to the "edge" temperature. This is done for a constant absorption coefficient and uniform heat generation. Next, an expression for the edge temperature is derived. These two equations give the desired equation for gas temperature from the center out to, and including, the edge temperature. Then this equation is rewritten for the case where the absorption coefficient is an arbitrary function of temperature. Next, similar equations are written for any specified variation of heat sources throughout the gas. Finally, a numerical computer solution to the transport equations is formulated and used to obtain answers from the exact radiant transport equation in order to check the accuracy of the approximate diffusion equations obtained. At intermediate opacities ($.1 \leq T \leq 10$), the approximate equations give temperatures that are within 3 percent of a numerical solution to the exact transport equation.

As an example, the general temperature distribution throughout a gas relative to a black-body temperature, T_{bb}, (defined so that σT_{bb}^4 = the radiated heat flux) is

$$T/T_{bb} = (0.5(1 + a/\tau + .375\,\tau(1-x^2)))^{1/4}$$

where a = 1, 2, or 3 for a slab, cylinder, or sphere respectively, and x is the dimensionless distance from the center to the edge of the gas region; i.e., Z/Ze for a slab, and R/Re for a cylinder or a sphere. The optical thickness τ is KL for a slab, and KD for a cylinder or a sphere.

Notes:

1. Additional documentation is available from:
   Clearinghouse for Federal Scientific and Technical Information
   Springfield, Virginia 22151
   Price $3.00
   Reference: TSP69-10329
2. Technical questions may be directed to:
   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B69-10329

(continued overleaf)

Patent status:

No patent action is contemplated by NASA.

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